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Measurements of partial branching fractions for $B \rightarrow X_u l \nu$ and determination of $|V_{ub}|$ at BaBar

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Summary. — We present partial branching fractions for inclusive charmless semileptonic B decays $B \rightarrow X_u l \nu$, and the determination of the CKM matrix element $|V_{ub}|$. The analysis is based on a sample of 467 million $\Upsilon(4S)$ decays into $B\bar{B}$ pairs collected with the BaBar detector at the *PEP-II* e^+e^- storage rings. The invariant mass of the hadronic system, M_X , the squared invariant mass of the lepton pair, q^2 , and the variable $P_+ = E_X - |P_X|$ and their combinations, in the process $B \rightarrow X_u l \nu$ are used as discriminant variables to suppress semileptonic decays with charm. Partial branching fractions are measured as a function of the cuts on the above variables. Theoretical calculations are used to compute acceptances and related uncertainties, thereby allowing to extract $|V_{ub}|$.

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1. – Introduction

In the Standard Model, the elements of the Cabibbo-Kobayashi-Maskawa matrix [1,2] describe the coupling between the quarks and the weak charged currents. By construction, this matrix is unitary and one of the unitarity conditions can be represented graphically by the so-called Unitarity Triangle (UT). The angles and sides of the UT can be measured by studying B -meson decays. The determination of $|V_{ub}|$ matrix element is particularly interesting since it is one of the smallest and least known matrix elements. In addition divided by $|V_{cb}|$ it measures the side of the UT opposite the well-known angle β (uncertainty 4% [3,4]). While the determination of $|V_{cb}|$ is at the 2% level [5], the uncertainty on $|V_{ub}|$ is still at the 9% level [6,7]. The need for an improvement in the precision on $|V_{ub}|$ is therefore evident.

2. – Analysis technique

In this paper, we present a measurement of partial branching fractions for inclusive charmless semileptonic decays, $B \rightarrow X_u l \nu$. $\Upsilon(4S) \rightarrow B\bar{B}$ events are tagged by the full reconstruction of a hadronic decay of one of the B -mesons (B_{reco}). The semileptonic decay of the second B -meson (B_{recoil}) is identified by the presence of an electron or a

TABLE I. – Summary of the fitted number of signal events and extracted $|V_{ub}|$ for the four kinematic regions. The first uncertainty is statistical, the second systematic, and the third is due to BLNP theoretical model [8]. The total uncertainty in percent is shown in the last column. The number of semileptonic decays is N_{SL} .

Phase space region	$N_{b \rightarrow u}$	$ V_{ub} \times 10^{-3}$ from BLNP [8]	Error
$m_X < 1.55 \text{ GeV}/c^2$	1073 ± 73	$3.92 \pm 0.14_{stat} \pm 0.10_{syst} \pm 0.30_{theo}$	8.8%
$P_+ < 0.66 \text{ GeV}/c^2$	894 ± 61	$3.74 \pm 0.13_{stat} \pm 0.12_{syst} \pm 0.29_{theo}$	9.1%
$m_X < 1.7 \text{ GeV}/c^2, q^2 > 8 \text{ GeV}^2/c^2$	713 ± 53	$4.24 \pm 0.16_{stat} \pm 0.13_{syst} \pm 0.33_{theo}$	9.2%
m_X, q^2 full phase space	1568 ± 101	$4.34 \pm 0.16_{stat} \pm 0.16_{syst} \pm 0.23_{theo}$	7.4%

muon (extracted about 222000 $B \rightarrow Xl\nu$ decays). This technique results in a low event selection efficiency but allows the determination of the momentum, charge and flavour of the B -mesons. Experimentally, the principal challenge is to separate the rare $B \rightarrow X_u l \nu$ decays from the approximately 50 times larger $B \rightarrow X_c l \nu$ background. Given that the u -quark is much lighter than the c -quark, regions of phase space can be defined where the background is suppressed. We use three kinematic variables to separate $B \rightarrow X_u l \nu$ decays from the dominant $B \rightarrow X_c l \nu$ background: m_X , the invariant mass of the hadronic system $X_{u,c}$; q^2 , the invariant mass squared of the lepton-neutrino system; and $P_+ = E_X - |P_X|$, where E_X and P_X are the energy and three-momentum of the hadronic system $X_{u,c}$ calculated in the B rest frame. We measure the fraction of partial rates of charmless semileptonic decays $\Delta R_{u/sl} = \Delta \mathcal{B}(B \rightarrow X_u l \nu) / \mathcal{B}(B \rightarrow X l \nu)$ in restricted phase-space regions corrected for resolution effects in order to reduce systematic uncertainties. To relate the decays rate of the B -meson to V_{ub} , parton level calculations have to be corrected for perturbative and non-perturbative QCD effects. QCD calculation is available to determinate these corrections [8].

3. – Results and conclusions

In table I the number of signal events and the extracted $|V_{ub}|$ values with their uncertainties are reported for the four kinematic regions analyzed. The results presented here are slightly better in precision (about 10%), with respect to inclusive measurements published by BaBar [6] and Belle [7] with similar technique. At present the inclusive determination is only marginally compatible with the exclusive determination. The two approaches differ by about 2σ . These discrepancies have to be understood in the next future.

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